CLASS 9TH

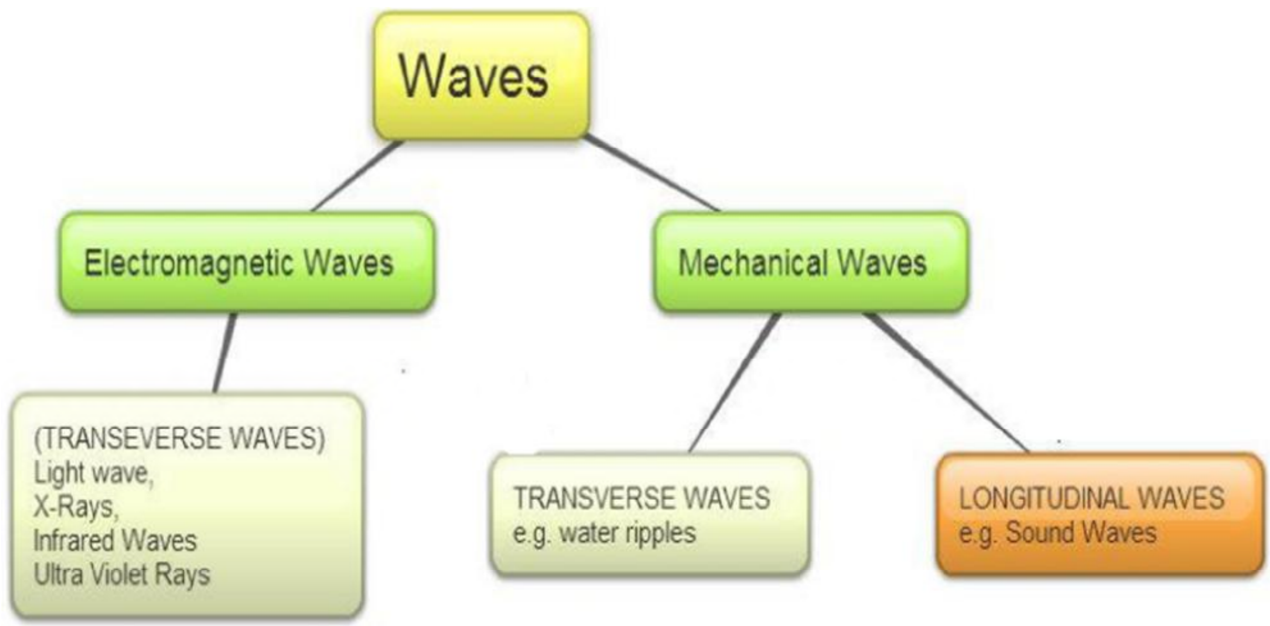
SOUND

What is a wave?

- A wave is a disturbance produced in a medium as the particles of the medium vibrate.
- The particles produce motion in each other without moving forward or backwards.
- This leads to the propagation of sound.
- Hence sound is often called a **Wave**.

What are mechanical waves?

A wave that is produced when objects of the medium oscillate is called **Mechanical Wave**. The sound waves are therefore, mechanical waves.

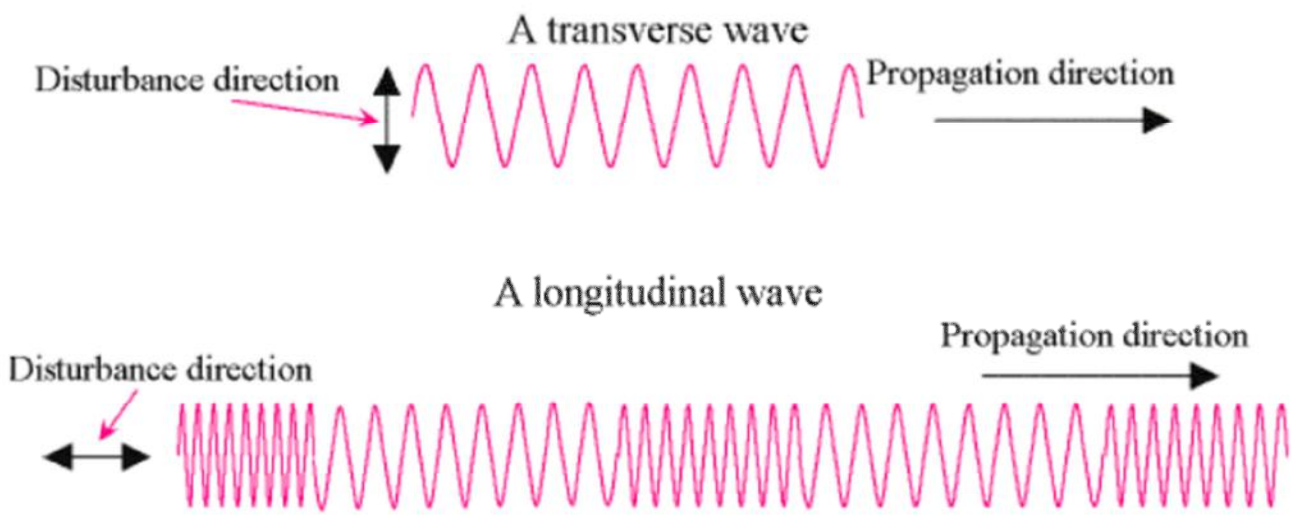


Types of Waves

- Sound cannot travel through the vacuum as it always needs a medium to propagate. The vacuum contains no air hence no particles can propagate sound.

Longitudinal waves - Any wave that vibrates in the direction of the motion is called a **Longitudinal Wave**. Sound waves are longitudinal because the particles of the medium vibrate in the direction which is parallel to the direction of the propagation of the sound waves. The particles in the medium oscillate to and fro in the case of longitudinal waves.

Transverse Waves - A transverse wave is produced when the particles of the medium oscillate in a direction which is perpendicular to the direction of the propagation of the wave. The particles in a transverse wave oscillate in an up and down motion. **For Example**, light waves are transverse in nature.

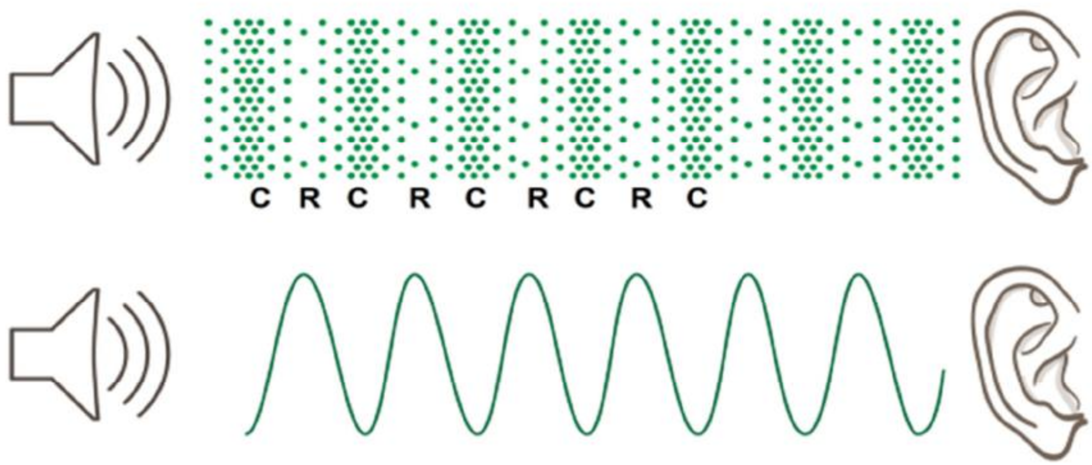


Longitudinal vs. Transverse Waves

How can sound travel through air?

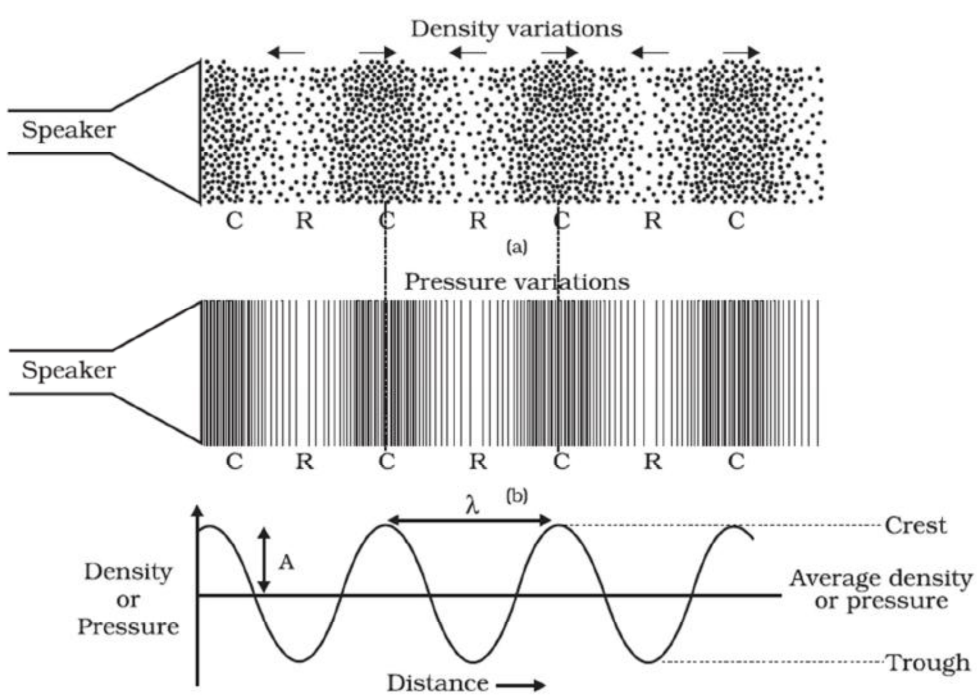
- When an object vibrates in the air or produces a sound, some regions of high pressure are created in front of it. These are called the **Regions of Compression**. These regions of compression move forward in the medium as particles exert pressure on their adjacent particles.
- With alternate regions of compression, there are also regions of low pressure that are in its front. These are called **Regions of Rarefaction.**
- As the object would move forwards and backwards consecutively producing sound, the series of compressions and rarefactions will be created. This will allow sound to move through air or any other medium as well.

- If the medium is dense the pressure exerted on the particles will be more in order to propagate the sound and vice versa.
- Therefore, we can also say that propagation of sound is all about change in the pressure of the medium.

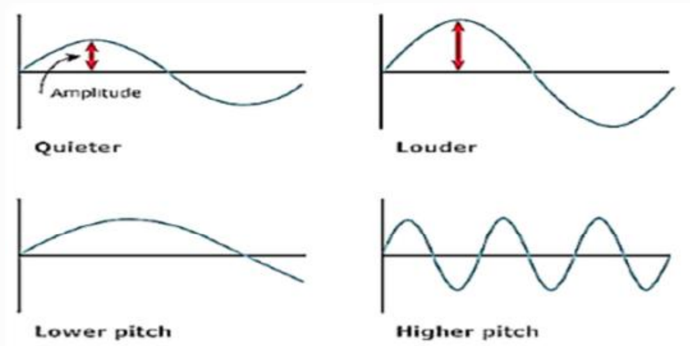
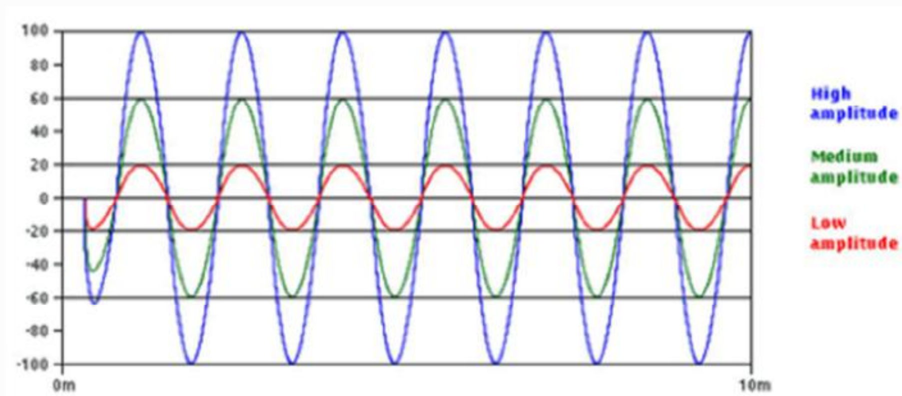
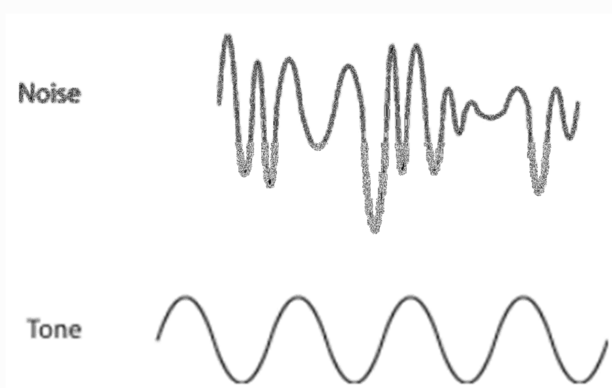


Sound wave causing compression (C) and refraction (R)

CHARACTERISTICS OF SOUND WAVE



Compression (C)	The compression region is represented by the upper part of the wave curve. It is a region where particles cluster together. The density, as well as pressure, is always high in this region.
Refraction (R)	A refraction is represented by the lower part of the wave curve. It is a region where the particles separate out. Refraction region always has lower pressure.
Crest	It is the peak of the curve
Trough	It is the crust of the curve
Wavelength (λ)	The distance between two consecutive compressions or refractions is called **Wavelength**. SI unit: metre (m)
Frequency (f)	The number of oscillations per unit time is called the **Frequency of a Wave** (Number of compressions + the number of refractions per unit time) SI unit: Hertz (Hz)
Time Period (T)	The time taken between two consecutive compressions or refractions to cross a fixed point is called **Time Period of the Wave**. In other words, the time taken for one complete oscillation through a medium is called a **Time Period**. SI unit: second (s)
The relationship between frequency and time period	$f = 1/T$
Pitch	Pitch of a sound depends upon: 1. the frequency of the sound 2. size of the object producing the sound 3. type of the object producing the sound

	
Amplitude	The value of the maximum or minimum disturbance caused in the medium is called the **Amplitude of the Sound**.. Amplitude defines if the sound is loud or soft. 
Timber	The timbre or quality of sound is a characteristic with which we can differentiate between different sounds even if they have same pitch and amplitude.
Tone	The sound which has single frequency throughout is called a **Tone**.
Note	A sound with more than one frequency is called a **Note**. It is pleasant to listen
Noise	It is an unpleasant sound. 

Music	It is a sound which is pleasant and has rich quality
The Speed of sound (v)	The distance by which a compression or refraction of a wave travels per unit time is called as **Sound's Speed**. SI unit: metres/seconds v = wavelength / time = $\lambda/T = \lambda*F$ Speed of Sound in air = 333 m/s
Intensity	The amount of sound energy that passes through a unit area per second is called its intensity
Loudness	It is how our ears respond to a sound. Two sounds with same intensity can vary in loudness only because we can detect one sound easier than the other.

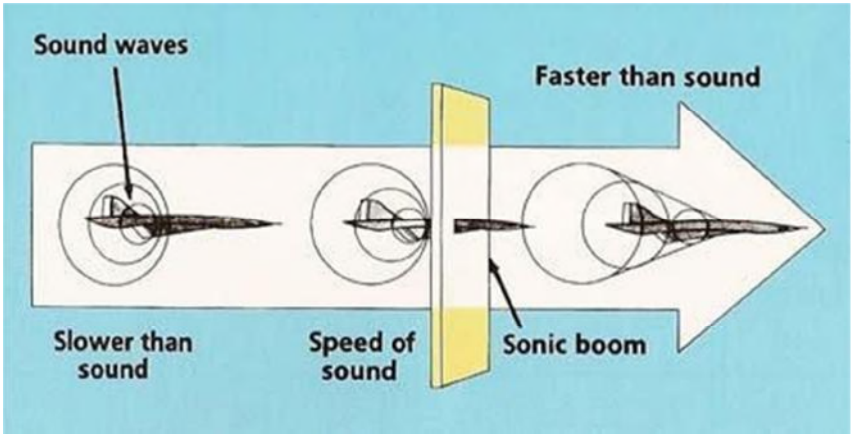
Sound cannot travel at the same speed in different mediums. The speed of sound in a medium is affected by three things:

- The density of the medium. For instance, speed of sound is the maximum through solids
- The temperature of the medium. As the temperature increases, the sound propagates easily.
- Humidity in the air also affects the travel of sound. As the humidity increases, so does the propagation of sound.

What is a sonic boom?

When an object travels in the air with a speed greater than that of the sound, it produces a sound with high energy. This energy is loud enough that it can break glasses or damage the buildings. The sound produced is similar to the sound of an explosion or thunderclap.

These objects exert a large amount of pressure on the air which causes the production of shock waves in the air. These shock waves produce extremely large and loud sound waves which are called Sonic booms.



Sonic Boom

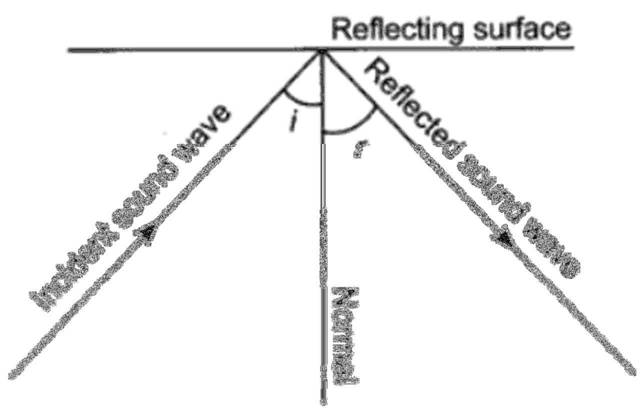
- Speed of light in air = 3 * 10^8 m/s
- Speed of sound in air = 333 m/s

This clearly states that sound travels a lower speed than that of light in air. This is a reason why at the time of lightening, the light is visible instantly while the sound of the thunder reaches our ears after a few seconds.

- Sound can bounce off a solid or a liquid. Some materials like metals and walls are called **Good Reflectors of Sound** as they do not absorb the sound while others like clothes and sponge are called **Bad Reflectors of Sound** as they absorb the sound easily.

Laws of Reflection of Sound

- The incident sound wave, the reflected sound wave and the normal, all lie in the same plane.

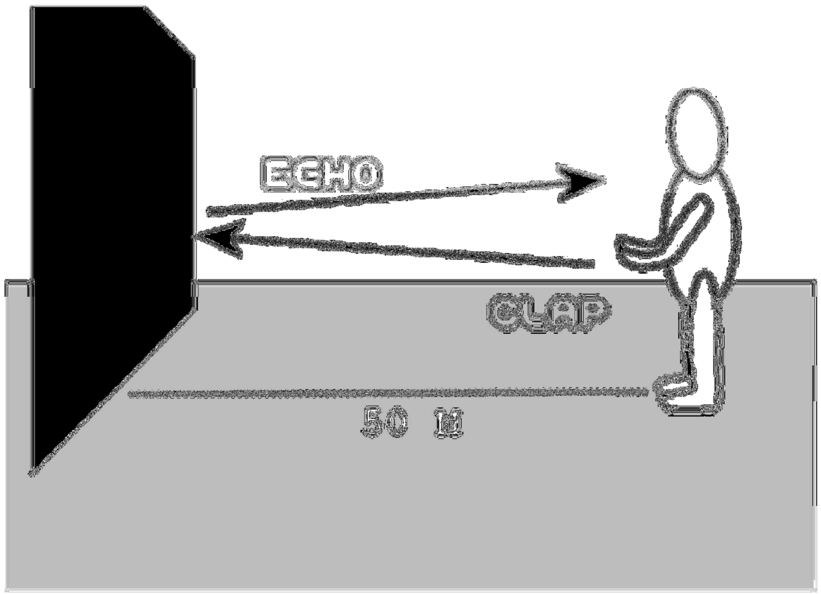


Laws of Reflection of Sound

- The angle of incident of incident sound wave is equal to the angle of reflection formed by the reflected sound wave, that is, i = r

Echo

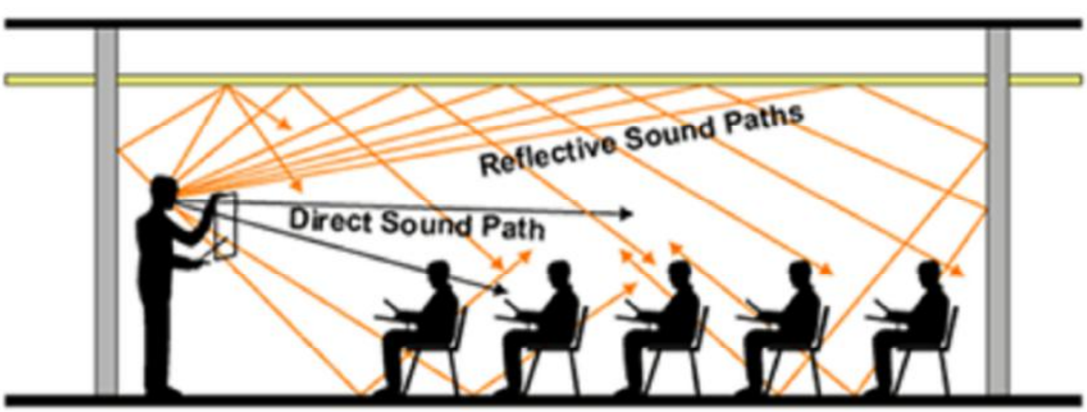
When we hear the same sound again and again in a medium it is called **Echo**. The sound or echo persists in our brain for 0.1 seconds. This means that the difference between sound and its echo should be at least 0.1 seconds. It is produced as a result of reflection of sound through a medium. If sound reflects more than once we may hear multiple echoes.



Echo

Reverberation

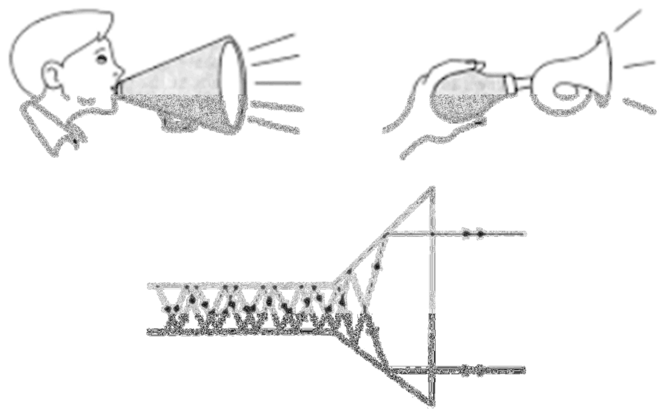
It is the persistence of a sound after a sound is produced. A reverberation is created when a sound signal is reflected multiple of times until it reaches a sound wave that cannot be heard by human ears. Auditoriums and big halls often have to deal with reverberation. That is why the roofs are made up of soundproof materials like Flipboard and the chairs in the halls are also made up of fabrics that can absorb sound.



Reverberation

Advantages of Multiple Reflection of Sound

- Horns, trumpets, loudhailers or megaphones are designed in such a way that sound can travel in a particular direction only without spreading out everywhere. This makes it easier for the audience to listen to the speaker. All these instruments work on the phenomena of multiple reflections of sound.



Multiple Reflections through a horn and megaphone

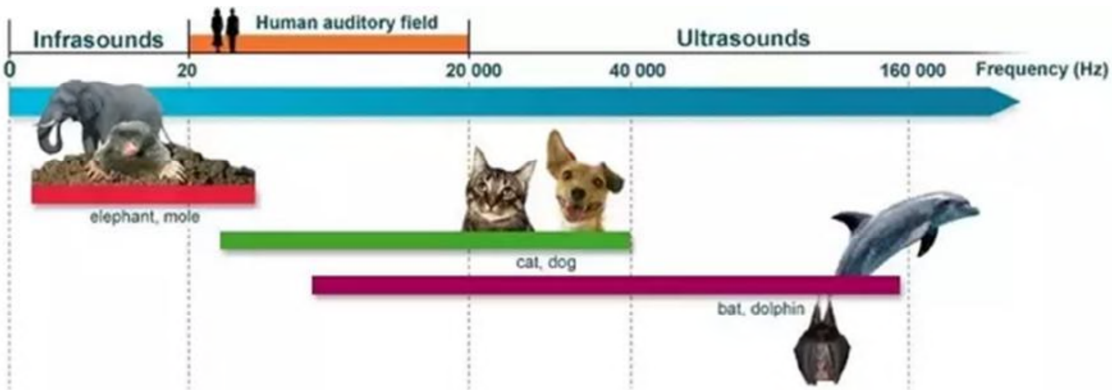
- The multiple reflections in a stethoscope tube make it possible for the doctors to listen to a patient's heartbeat.
- Concert halls are generally covered so that sound can reflect through it and reach the wider audience.

The range of sound – on the basis of the range of frequency of a sound, it is categorized into *ultrasound* and *infrasound.*

Human auditory range is between 20 Hz and 20000 Hz.

Infrasound	Ultrasound
Infrasound refers to the sound with frequency lower than 20 Hz which can't be heard by humans.	Ultrasound refers to the sound with frequency higher than the upper limit (20 kHz) of frequencies audible to normal human ears.
Infrasound is used to stabilize myopia in young kids.	Ultrasound is commonly used to find flaws in materials to measure the thickness of objects, to fund physical abnormalities in various parts of human body, as well as in the form of a sound ranging

	device called Sonar.
Infrasound is influenced by the atmosphere so it can be used to monitor the activities of the atmosphere.	Ultrasound is not influenced by any such factors.
In particular, natural disasters such as volcanic eruptions, earthquakes etc can be forecasted by monitoring the infrasonic waves.	In particular, ultrasound is also used in micro welding. The weld is produced by the application of higher frequency vibratory energy as the parts are held together with force.



Range of Infrasound and Ultrasounds

Hearing Aid- The Hearing Aid contains a microphone which receives the sound from the outer atmosphere and converts it into electrical energy. This electrical energy is passed through an amplifier which amplifies the sound and then moves it to a speaker. The speaker then converts the electrical signal into sound waves and sends it to the ear and provides a clear hearing.

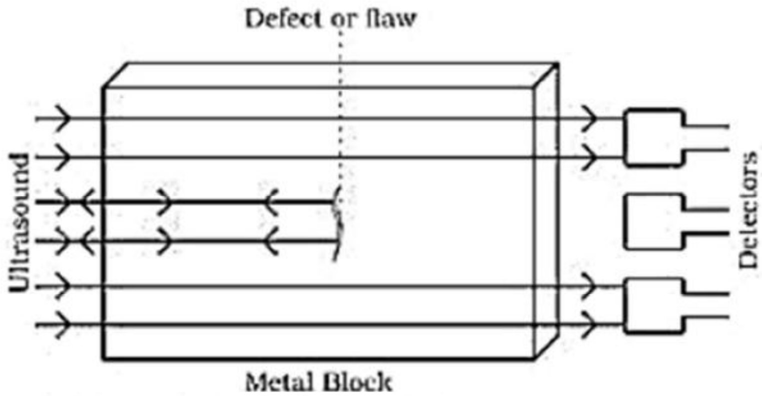
Applications of Ultrasound

The ultrasound waves are the sound waves with high frequency. Due to this, they can travel long distances despite any obstacles between their paths.

- The ultrasound waves are used in clearing parts of objects that are hard to reach such as a spiral tube or electronic components. In order to clean the objects, they are put in a solution, and then the ultrasonic waves are passed

through the solution. As a result, the dust particles on the object get detached and fall off them.

- Ultrasound waves can recognize tiny cracks in metallic objects that are used in the manufacture of large structures, buildings and scientific equipment. The presence of such cracks can lower the strength of these structures and machines. Hence, the ultrasound waves are passed through the metallic objects and detectors are used to detect the waves that pass through the cracks. If a crack is present the ultrasound waves would reflect back.

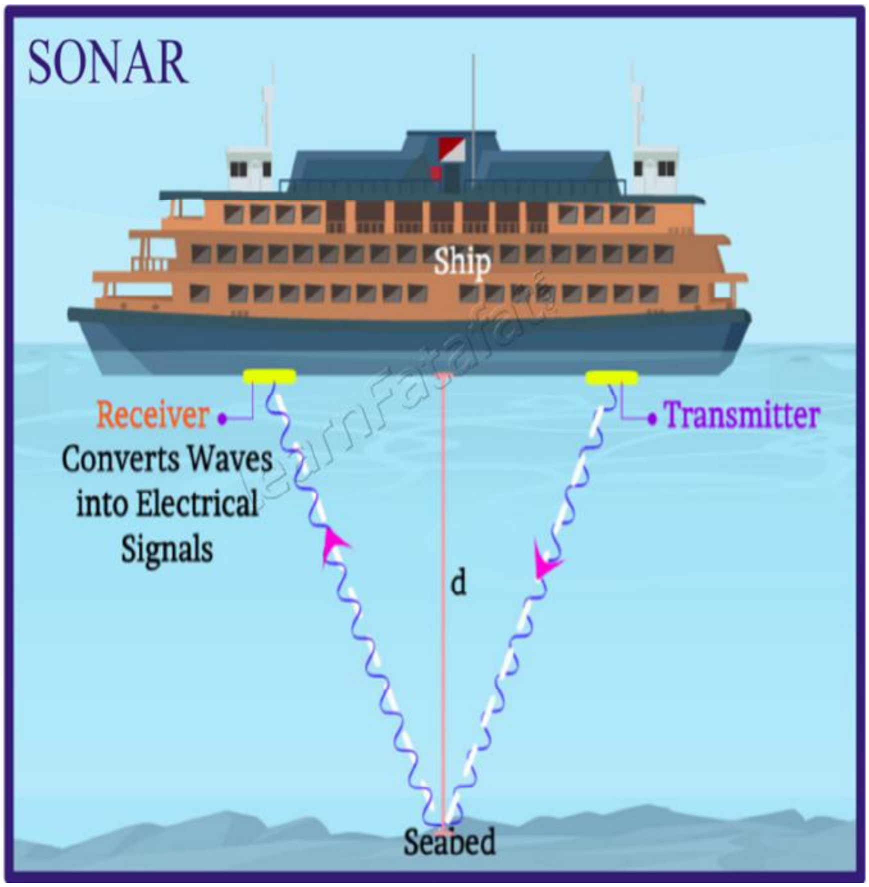


Ultrasound is reflected back from the defective locations inside a metal block.

Ultrasound waves can detect cracks in a metal

- Ultrasonic waves are also used in a medical process called **Echocardiography**. In this process, the ultrasound waves are passed through various parts of the heart in order to form the images of the organ.
- Ultrasonic waves are also used in a procedure called **Ultrasonography**. In this procedure, the ultrasonic waves are passed through the internal organs of the body in order to get their image. In this way, the doctors can find out the cause of a disease or any abnormalities in the organs. The ultrasound waves travel through the tissues of the body and as soon as the density of the tissue changes they reflect back. The reflected waves are then converted into electrical signals which form the images of the internal organs.
- Ultrasound waves are also used to break the kidney stones.

SONAR – Sound Navigation and Ranging

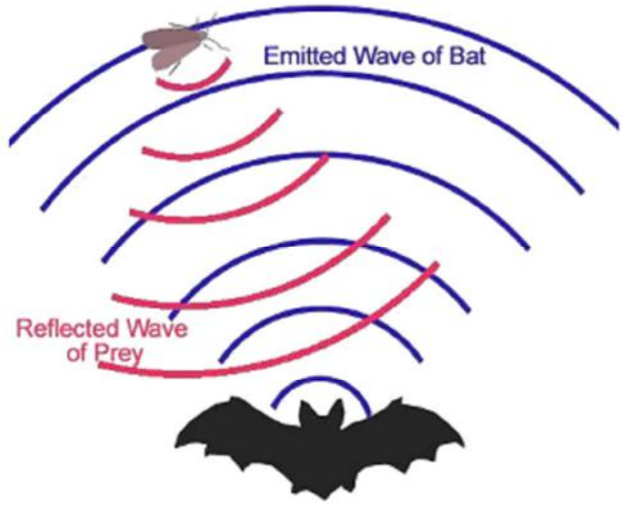


SONAR

- This device is used to find the distance, direction and speed of objects that are present under the water. It uses Ultrasonic waves to do so.
- The Sonar consists of two main devices – The transmitter and the detector (or receiver). The main function of the transmitter is the production and transmission of the Ultrasonic waves in water.
- As these waves travel underwater, they, when hit by an object, reflect back to the detector. The detector then converts these sound waves into electrical signals which are then interpreted.
- The distance of the object is calculated with the help of the speed of sound in water and time taken by the way to reach the detector. This process is called **Echo Ranging.**
- Uses of SONAR
    - Finding the depth of a water body such as sea
    - Detecting the presence of underwater objects like submarines, hills, icebergs and ships

How do bats search their prey?

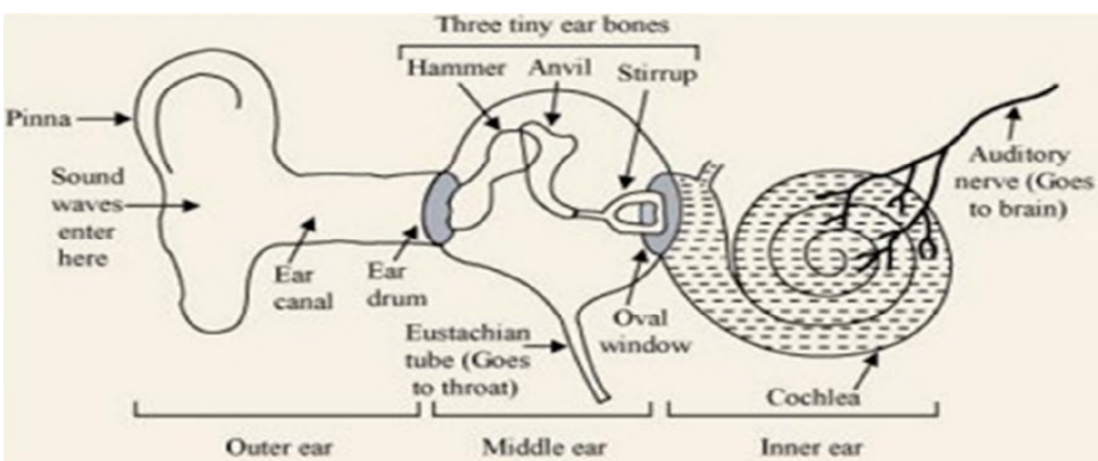
Bats generate Ultrasonic waves. As these waves hit an object, they get reflected back to the bat's ears. The bats can understand the nature of reflection of these waves and then can decide the position of the object over their prey.



Ultrasonic waves generated by bats

Human Ear

The human ear is an organ whose main function is to hear and to detect the noise. When noise is made sound waves are converted into the electrical impulse. In mammals, the ear is used for the sense of balance. The compression of air is converted into electrical signals so that the brain can detect sound. In the structure of the ear, we will understand how the process of conversion of air compression into an electrical signal takes place.



There three parts of the ear

Outer Ear

It contains a pinna (board part), ear canal (2-3 cm long passage) and Eardrum/ Tympanum (thin, circular elastic membrane at the end of the ear)

Middle Ear

It consists of three small and delicate bones hammer, anvil and stirrup. They are linked to each other. The lower part of the middle ear called a narrow tube called a Eustachian tube. Kit connects the middle ear to the throat. Air pressure inside middle ear is same as outside.

Inner Ear

It consists of a coiled tube called cochlea which is connected to the middle ear through the elastic membrane over the window. The cochlea is filled with a liquid which contains nerve cells which are sensitive to the sound. The other side of the nerve is connected to the auditory nerve which goes into the brain.

WORKING

The compression in the air reaches the outer car called pinna which detects the sound to travel through the ear canal to reach the car drum. Due to these compressions, the membrane starts vibrating. This thin membrane vibrates and relaxes depending on the amplitude of compression in the air. The vibration is then passed to three bones in the ear connected to the eardrum: hammer, anvil and stirrup and is amplified about 20 times than the actual vibration.

After the amplification by ear bones, the vibration is passed through the oval ear called Cochlea. Then vibration is sent to the liquid present in it, it creates waves and gets the electrical signal out of the cochlea. This creates waves and gets the signal out of the cochlea. The signal is sent through auditory nerve and brain reads the electrical impulse and detects the sound.

ADDITIONAL QUESTIONS

Q1. How does the sound produced by a vibrating object in a medium reach your ear?

Answer:

When an object vibrates, it forces the neighbouring particles of the medium to vibrate. These vibrating particles then force the particles adjacent to them to vibrate.
In this way, vibrations produced by an object are transferred from one particle to another till it reaches the ear.

Q2. Explain how sound is produced by your school bell.

Answer:

When the school bell vibrates, it forces the adjacent particles in air to vibrate. This disturbance gives rise to a wave and when the bell moves forward, it pushes the air in front of it. This creates a region of high pressures known as compression. When the bell moves backwards, it creates a region of low pressure know as rarefaction. As the bell continues to move forward and backward, it produces a series of compressions and rarefactions. This makes the sound of a bell propagate through air.

Q3. Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium.

Answer:

Speed of the sound wave, $v = 440 \text{ m s}^{-1}$

For a sound wave,

Speed = Wavelength × Frequency

$v = \lambda \times \upsilon$

$$\therefore \lambda = \frac{v}{\upsilon} = \frac{440}{220} = 2 \text{ m}$$

Hence, the wavelength of the sound wave is 2

Q4. An echo returned in 3 s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m s−1?

Answer:

Speed of sound, v = 342 m s−1

Echo returns in time, t = 3 s
Distance travelled by sound = v × t = 342 × 3 = 1026 m
Hence, the distance of the reflecting surface from the source = (1026/2)m= 513m

Q5. A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?

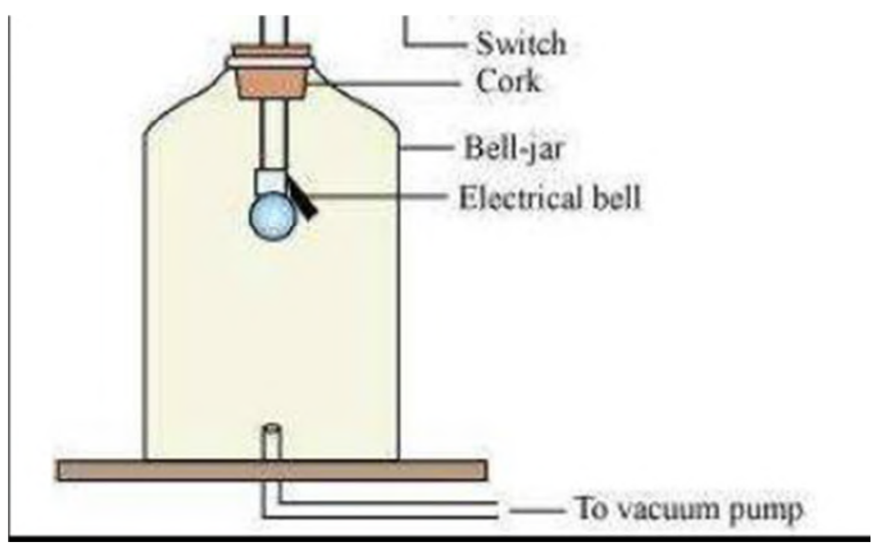
Answer:

Time taken by the sonar pulse to return, t = 1.02s

Speed of sound in salt water, v = 1531 m s−1
Distance of the cliff from the submarine = Speed of sound × Time taken
Distance of the cliff from the submarine = 1.02 x 1531 = 1561.62m
Distance travelled by the sonar pulse during its transmission and reception in water = 2 ×Actual distance = 2d
Actual Distance , d = (Distance of the cliff from the submarine)/2 = 1561.62/2 = 780.31 m

Q6 Cite an experiment to show that sound needs a material medium for its propagation.

Answer:
Take an electric bell and hang this bell inside an empty bell-jar fitted with a vacuum pump (as shown in the following figure).



Initially, one can hear the sound of the ringing bell. Now, pump out some air from the bell jar using the vacuum pump. It will be observed that the sound of the ringing bell decreases. If one keeps on pumping the air out of the bell-jar, then at one point, the glass-jar will be devoid of any air. At this moment, no sound can be heard from the ringing bell although one can see that the prong of the bell is still vibrating. When there is no air present inside, we can say that a vacuum is produced. Sound cannot travel through vacuum. This shows that sound needs a material medium for its propagation.

Q7. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?

Answer:

The speed of sound (344 m/s) is less than the speed of light (3 x 10^8 m/s). Sound of thunder takes more time to reach the Earth as compared to light. Hence, a flash is seen before we hear a thunder.

Q8. A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s–1.

Answer:

For a sound wave,
Speed = Wavelength × Frequency
$V = \lambda \times f$

Given that speed of sound in air is 344 m/s
For v= 20Hz
$\lambda = \frac{344}{20} = 17.2$ m
For v = 20kHz

$\lambda = \frac{344}{20000} = 0.0172$ m
Hence, for humans, the wavelength range for hearing is 0.0172 m to 17.2 m.

Q 9. The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?

Answer:

Frequency is defined as the number of oscillations per second. It is given by the relation:

Frequency = Number of Oscillations / Total Time

Number of oscillations = Frequency × Total time

Given, Frequency of sound = 100 Hz

Total time = 1 min = 60 s

Number of oscillations/Vibrations = 100 × 60 = 6000

Hence, the source vibrates 6000 times in a minute, producing a frequency of 100 Hz.

Q10. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, g = 10 m s−2 and speed of sound = 340 m s−1.

Answer:

Height of the tower, s = 500 m

Velocity of sound, v = 340 m s−1

Acceleration due to gravity, g = 10 m s−2

Initial velocity of the stone, u = 0 (since the stone is initially at rest)

Time taken by the stone to fall to the base of the tower, t1

According to the second equation of motion:

$$s = ut_1 + \frac{1}{2}gt_1^2$$

$$500 = 0 \times t_1 + \frac{1}{2} \times 10 \times t_1^2$$

$$t_1^2 = 100$$

$$t_1 = 10\ \text{s}$$

Now, time taken by the sound to reach the top from the base of the tower,

$$t_2 = \frac{500}{340} = 1.47\ \text{s}$$

Therefore, the splash is heard at the top after time, t

Where, $t = t_1 + t_2 = 10 + 1.47 = 11.47\ \text{s}$